METHOD, APPARATUS AND SYSTEM FOR SELECTIVE RELEASE OF CEMENTING PLUGS

Field of the Invention

The present invention relates to cementing pipe within a wellbore. More particularly, the present invention relates to selectively releasing wiper plugs contained within enclosed launching assemblies for cementing casing, subsea casing strings and casing liners in wells.

Background of the Invention

Pipe used to case wellbores is cemented into the wellbore to anchor the well pipe and isolate differently pressured zones penetrated by the wellbore. Pipe used for this purpose is generally referred to as "casing." The cementing step is initiated by pumping a cement slurry down into the casing from the well surface. The cement slurry flows out from the bottom of the casing and returns upwardly toward the surface in the annulus formed between the casing and the surrounding wellbore.

In the cementing process, the fluid normally used in the drilling of the wellbore, referred to herein generally as "drilling fluid," is displaced from the casing ahead of the cement slurry pumped into the casing. When a sufficient volume of the cement slurry has been pumped into the well pipe, drilling fluid is used to displace the cement from the well pipe to prevent the pipe from being obstructed by the cured cement.

The drilling fluid and cement slurry are separated during the displacements with appropriate liquid spacers, or more preferably, with sliding wiper plugs that seal along the inside of the well pipe, wiping the inside of the pipe and isolating the cement slurry from the drilling fluid. When using wiper plugs to separate the drilling fluid and cement, the cement slurry is pumped

behind a first wiper plug to push the plug through the casing, forcing the drilling fluid in the casing to flow ahead of the plug. The drilling fluid displaced from the bottom of the casing flows upwardly through the annulus and returns toward the well surface.

When a sufficient volume of cement has been pumped behind the first wiper plug, a second wiper plug is positioned in the casing and drilling fluid is pumped into the casing behind the second plug to push the cement slurry through the casing. A flow passage in the first plug opens when it reaches the casing bottom to permit the cement slurry to flow through and past the plug, out the casing bottom. Once the first wiper seal has been opened and its seal terminated, the continued advance of the second plug through the casing displaces the cement slurry past the first plug, around the end of the casing, and up into the annulus. The second plug stops and maintains its sealing engagement with the casing once it arrives at the bottom of the casing.

When the casing string extends back to the drilling rig, the first and second plugs and cement are manually inserted into the casing at the drilling rig floor. Remotely set plugs are used when the well casing that is to be cemented does not extend back to the drilling rig floor. For example, a "liner," which is a string of casing that hangs from the bottom of a previously installed larger diameter section of casing, does not extend back to the drilling rig floor. Subsea completions in offshore wells also involve strings of casing that do not extend back to the drilling rig.

Installing and cementing strings of casing that do not extend to the drilling rig is typically done by installing the casing string with a smaller diameter running string. If wiper plugs are employed in this process, they are carried on a running tool at the lower end of a small diameter string of drill pipe that extends from the drilling rig and connects to the top of the larger diameter casing string that is to

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be cemented. The drilling fluid and the cement slurry required to perform the cementing operation are initially pumped from the surface through the small diameter drill pipe, through circulating openings in the wiper plugs and into the casing. The plugs are "remotely set" from the rig floor using setting devices that are inserted into the string at the rig floor and pumped down to the plugs carried on the running tool. The cement slurry exiting the bottom of the casing string returns in the annulus to the point at which the casing string is hung off from the higher casing string or sub sea wellhead.

In a typical operation of remotely set wiper plugs carried at the end of a running tool on a drill string, a brass ball, or a weighted plastic ball or dart or other setting device is inserted into the drill string at the surface ahead of the cement slurry. The ball passes through the opening in the upper wiper plug and lands in and closes a smaller circulation opening in the lower plug. The resulting pressure increase releases the lower plug for movement through the casing. When sufficient cement has been pumped into the drill string and casing from the surface, a latch-down plug or seal dart is inserted into the drill string and pumped down to the upper wiper plug still secured to the running tool. Arrival of the latch-down plug at the upper plug closes the circulation opening and releases the upper plug for movement through the casing string. The upper plug is then pumped to the bottom of the casing to completely displace the cement slurry from the casing.

Remotely set wiper plugs are also employed in rig floor cementing assemblies that employ multipurpose tools that function as combination fillup tools and cementing tools. These combination tools, as described in U.S. Patent No. 5,918,673, may include remotely releasable plugs in the surface operated assembly to eliminate the need for a separate plug container or other similar device at the rig floor for deploying the cementing plugs.

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A common requirement of remotely set wiper plugs, including those used in the combination tool assembly, is the need for the plugs to accommodate circulation of fluids before they are released to travel through the casing string. The size of circulation openings is a major consideration in the design of the wiper plugs and their launching mechanisms.

In use, the materials and components of the wiper plug must withstand the pumping pressure differentials and the erosion experienced during different phases of the cementing procedure. Any sealing surface exposed to the flow of the cement slurry and drilling fluids is subject to erosion damage and possible failure, particularly when the seals are formed of plastic or other non-durable materials. Accordingly, substantial volumes of durable material are required in the construction of conventional wiper plug assemblies to meet the strength and erosion resistance requirements imposed on the assemblies before their release.

The increased strength and durability of the plugs are typically achieved at the expense of the size of the circulation openings through the plugs. Because of their relatively small circulation openings, remotely set wiper plugs carried in a combination tool or connected with the drill pipe can create a restricted flow passage for pumped fluids. These flow restrictions can increase the possibility of packing off and other problems and can limit pumping rates for the drilling fluids as well as the cement slurry.

The wiper plugs used in cementing must also be constructed of materials that may be easily drilled up or milled away at the end of the cementing operation. Because of this requirement, the use of high-strength metal is undesirable in the construction of the wiper plugs. The necessary strength and durability requirements are met in conventional wiper plugs by using larger volumes of soft metals and other easily removable materials. The required large

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volumes of material can require small passage openings that can contribute to the restriction of flow of fluids through the wiper plugs.

The requirement for relatively large volumes of soft structural metal or durable plastics within conventional, remotely actuated wiper plugs also renders the use of certain designs impractical within smaller internal diameter well casings. For example, in well casings having an internal diameter of 7" or less, the volume of materials required to provide the support and release functions of a plug with a conventional design limit the fluid bypass opening so that desired pumping rates cannot be effectively obtained. The limited bypass openings also increase the likelihood of packing off the bypass and prematurely launching the plug.

Conventional, multi-plug assemblies employed in remotely launched systems typically require different designs for each wiper plug that is to be deployed within the well casing. Each of the different designs includes a large volume of the special material required for the structural support, sealing and latch release functions of the plugs. The total cost of employing conventional plugs includes the cost of the disposable materials incorporated into the plug and the requirement for separately dimensioned and designed plugs for each of the wiper plugs employed in the multi-plug assembly.

Gravity deployed balls used to launch a wiper plug may present certain operational difficulties with remotely operated plug launching systems. In particular, the ball's position cannot be accurately determined as it falls through the drill string en route to the subsurface plug. The speed of travel of the ball through the drill pipe is affected by gravity and by the flow rate and viscosity of fluid being pumped through the drill string. The effect due to gravity can become particularly problematic when the drill pipe extends through non-vertical orientations common in directionally drilled wells.

An alternative to employing balls as the release activating mechanism for the plug is to employ pump-down darts that can be displaced through the drill pipe ahead of the well fluid or cement slurry being pumped down into the casing. The benefit of the dart release mechanism is that its position can be accurately determined by measuring the volume of fluid being pumped into the pipe behind the dart. The dart also functions as an effective wiping structure that cleans the internal surface of the drill pipe as it is being pumped down to the plug.

An additional benefit of pump-down darts is that the dart may be rapidly forced through the drill string and into position within the wiper plug deployment tool. By contrast, the time required for a ball to eventually reach the wiper plug system under the force of gravity assisted by cement or drilling fluid flow is unpredictable.

Remote cementing plug launching systems that can easily accommodate a ball are not necessarily capable of functioning with a pump-down dart because of the limited axial development of the launching system. When the system employs multiple plugs that are to be deployed from a single running tool, the axial spacing between the release mechanisms of the plugs can preclude the effective use of pump-down darts.

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Summary of the Invention

The present invention provides a cementing running tool with wiper plugs having large circulation openings that allow increased bypass flow of drilling fluids and cement slurries. The plugs are constructed using a minimal amount of material, which permits large circulation openings and also reduces the amount of material to be milled out at the completion of the cementing process. The running tool provides a central, thin-walled tubular mandrel and release sleeves constructed of high-strength steel that support the wiper plugs and protect them from erosion while they are attached to the tool.

A ball or dart may be used to release the wiper plugs from the mandrel. The steel mandrel and the ball or dart used to release the wiper plugs remain with the running tool, eliminating the problem of drilling up or milling those components. Easily drillable flapper valve closure devices carried on the wiper plugs close the circulation openings when the plugs are deployed from the running tool to eliminate the need for the releasing ball or dart to be sent to the bottom of the casing as is done in many prior art designs. The seal surfaces for the circulation openings are protected from erosion by the running tool. Multiple plugs run in series may be of similar design to reduce construction costs.

The system of the present invention employs high-strength steel in a relatively thin-walled mandrel and release mechanism of a retrievable running tool to support and subsequently deploy the cementing plug. The use of a retrievable thin-walled mandrel and release mechanism for supporting and providing the structure for release of the plug permits larger flow openings

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through the plug and, because the mandrel is reusable, reduces the total cost of employing the system.

An important feature of the present invention is the elimination of the use of a ball or dart that must remain in the wiper plug to act as the flow closure element for the deployed wiper plug. Because the ball and dart are retrieved with the mandrel, they may be constructed of any desired material without regard to their drillability. Moreover, retrieval of the ball or dart allows them to be reused to reduce costs.

A feature of the present invention is that the device used to close the flow opening in the wiper plug is an integral part of the plug assembly. A flapper gate secured to the plug body is automatically closed when the plug leaves the mandrel. During the pumping circulation phases of the cementing operation, the flapper gate and seat, which may be made of easily eroded material, are protected behind the release sleeve and mandrel preventing erosion of the sealing surfaces. By contrast, the seals in the retrievable parts of the running tool that are exposed to the pumped fluids in the system of the invention are constructed of a high-strength, erosion resistant material, such as high-strength steel.

Another important feature of the present invention is that substantially the entire cross-sectional seal area of the wiper plug is exposed to differential pressure during the pressure induced deployment of the plug from its supporting mandrel. Systems that apply a pressure differential over a more limited area produce a smaller separation force. The mounting of the wiper plugs to the

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mandrel is such that application of deployment pressure to the bottom plug does not stress the bypass provision for other higher plugs in the assembly.

A further feature of the present invention is that, in addition to protecting the seals and other vulnerable components of the wiper plugs, the thin-walled, high-strength, retrievable mandrel tube of the invention permits the use of plugs having a large central flow passage with a relatively small outside diameter for effective use in smaller casing sizes.

From the foregoing, it will be appreciated that an important object of the present invention is to provide cementing plugs that are run from a thin-walled, high-strength tubular mandrel and release structure that permits large bypass flow openings through the plugs to permit increased flow rates and protect the plugs from erosion during the pumping process.

A related object of the present invention is to provide a retrievable, high-strength, thin-walled running tool constructed of a high-strength steel that permits the use of plugs that have a relatively small outside diameter and a relatively large bypass opening to permit high flow rates of cement slurry and drilling fluids.

Yet another object of the present invention is to provide a cement plug deployment system and apparatus in which two or more plugs contained within the system have substantially the same design to minimize the cost of construction of the system.

Another object of the present invention is to provide a remotely operable cement plug system that can be activated by either balls or darts to selectively and separately deploy two or more wiper plugs from a retrievable running tool.

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It is also an important object of the present invention to provide a running tool mandrel and release mechanism constructed of a high-strength steel to provide a thin-walled retention and isolation structure for remotely running one or more cement wiper plugs wherein the mandrel and release mechanism are retrievable parts of the running tool.

Another important object of the present invention is to provide the remotely operated cementing plug assembly of the present invention within a combination fillup tool and cementing tool disposed above the drilling rig floor.

The foregoing features, objects and advantages of the invention, as well as others, will become more fully appreciated and better understood by reference to the following drawings, specification and claims.

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Brief Description of the Drawings

Figure 1 is a longitudinal sectional view of a cement plug launching system illustrating a pair of cement plugs mounted on the lower end of a running tool mandrel;

Figure 1A is an enlarged view of a portion of Figure 1 illustrating the bottom plug before downshifting of a release sleeve;

Figure 2 is a longitudinal sectional view similar to Figure 1 illustrating a bottom internal sleeve shifted downwardly prior to displacing a bottom plug from the system;

Figure 2A is an enlarged view of a portion of Figure 2 illustrating a bottom plug following downshifting of the release sleeve and before displacement of the plug from the running tool mandrel;

Figure 3 is a longitudinal sectional view of a launching system of the present invention illustrating a bottom plug deployed from a running tool mandrel;

Figure 4 is a longitudinal sectional view similar to Figure 3 illustrating a top internal sleeve shifted downwardly prior to releasing a top plug;

Figure 5 is a longitudinal sectional view similar to Figure 3 illustrating the running tool mandrel after release of both plugs; and

Figure 6 is a vertical elevation, partially in section, illustrating a combination fillup tool and cementing tool assembly equipped with a remotely set wiper plug launching system of the present invention.

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Description of the Illustrated Embodiments

A remotely releasable cement plug and running tool system of the present invention is indicated generally at 10 in Figure 1. The system 10 includes an axially extending upper plug indicated generally at 11 and an axially extending lower plug indicated generally at 12. The two plugs 11 and 12 are carried on a running tool indicated generally at 13. The system 10 is suspended from the lower end of a drill string 14 that extends to the well surface (not illustrated). The system 10 is illustrated disposed within an axially extending well casing 15 that is to be cemented into a wellbore in a surrounding formation (not illustrated). The casing 15 is supported from a liner hanger (not illustrated) that is also carried by the drill string 14. The upper and lower plugs 11 and 12 are releasably secured to a retrievable axially extending tubular mandrel 17 that extends through the plugs and forms a major component of the running tool 13. A central flow passage 17a extends axially through the mandrel 17.

The plugs 11 and 12 are preferably constructed of synthetic materials that are easily drilled away or milled up during the subsequent deepening or completion of the well following the cementing operation. The lower plug 12 is constructed substantially in the form of an elastomeric cylindrical body having an axially extending, circumferential outer seal 18. The outer seal 18 includes a number of annular cup seals 18a that extend circumferentially about the central body of the seal 18 and operate to effect a sliding, sealing contact with an internal cylindrical surface 15a formed within the casing 15. The seal 18 may be constructed of rubber, or other suitable elastomeric material.

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The outer seal 18 is mounted about a central tubular seal support 20. A flapper valve mount 21 is carried in the upper end of the seal support 20 for supporting a hinged flapper closure gate 22. The valve mount 21 encircles and forms a sliding inner seal with the mandrel 17.

Referring jointly to Figures 1 and 1A, the flapper valve mount 21 is provided with a tapered, annular seating surface 21a that is designed to mate with and seal against a corresponding annular seal surface 22a formed along the external rim of the flapper gate 22. As will hereafter be explained in greater detail, the flapper gate 22 springs to a closed position sealing a central opening 20a through the plug 12 when the lower plug is ejected from the mandrel 17. A frangible disk 23 carried centrally on the flapper gate 22 functions as a releasable seal that is adapted to be ruptured after engaging with the float assembly (not illustrated) at the bottom of the casing string 15 to reestablish a flow passage through the plug 12.

The lower plug 12 is held to the mandrel 17 by radially movable upper and lower sets of dogs 25a and 25b that extend through radial openings in the wall of the mandrel 17. Serrated end faces on the radially external end faces of the dogs in the dog set 25b engage the internal surface of the opening 20a within the seal support 20, locking the lower plug 12 to the mandrel and temporarily preventing axial displacement between the mandrel and the plug. The dog sets 25a and 25b are held radially extended by a central moveable closure member or release sleeve 27 that engages the radially internal ends of the dogs. When in the position illustrated in Figs. 1 and 1A, the sleeve 27 prevents the dogs in

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the dog set 25b from moving radially inwardly out of engagement with the seal support 20, thereby retaining the plug 12 on the mandrel.

The release sleeve 27 is equipped with external, reduced diameter sections 28a and 28b that permit release of the plug 12 when the sleeve is shifted axially downwardly. Down shifting of the sleeve 27 places the sections 28a and 28b in registry behind the radial ends of dog sets 25a and 25b, respectively, permitting the dog sets 25a and 25b to move radially inwardly, releasing the surrounding seal support 20 and associated plug 12.

The release sleeve 27 is initially secured temporarily to the surrounding mandrel 17 by shear pins 30. Annular, elastomeric O-ring seals 31, 32 and 33 are positioned about the sleeve 27 between the sleeve and the surrounding internal surface of the mandrel 17. The seal rings 31, 32 and 33 prevent leakage from the mandrel passage 17a through radial openings within the mandrel formed by the shear pins 30, dog sets 25a and 25b and large diameter radial ports 35 formed in the wall of the mandrel 17. As will also be described more fully hereinafter, downward shifting of the release sleeve 27 opens the large diameter radial ports 35 permitting flow from the mandrel into an annular pressure area A between axial ends of the plugs 11 and 12.

The flapper gate 22 is secured to the flapper valve mount 21 by a hinge pin 22b. A coil spring 22c biases the gate 22 from its opened position illustrated in Figure 1A to a closed position illustrated in Figures 3 and 4. The coil spring may be constructed of any suitable material that provides the necessary biasing force to move the gate to its closed position. Because of its small size and

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volume, spring steel may be employed for the spring 22c without significantly increasing the mill up time required to remove the wiper plug 12 at completion of the cementing operation.

A central annular flow plug seat 29 is provided within the release sleeve 27. As will hereinafter be described more fully, the seat 29 cooperates with a ball or dart inserted into and pumped down the drill string 14 from the surface to form a pressure responsive mechanism to effect the downward shift of the sleeve 27.

The upper plug 11 design is substantially equivalent to the lower plug 12 with the major distinction being that the flapper closure gate of the lower plug is equipped with a frangible disk that is not provided in the upper plug 11. The various components of the upper plug 11 have been identified with reference characters that are the same as those employed in the identification of corresponding elements of the lower plug 12 with the exception of the addition of the letter "U" before the reference characters referring to the upper plug 11. As will hereinafter be explained in greater detail, because the lower plug is first to be launched, the central opening through the upper plug 11 is greater than that of the lower plug 12.

In the operation of the remotely releasable cement plug assembly and running tool assembly of the system 10, the combined assembly is lowered axially into a well until it is positioned at the top of the casing string to be cemented into the wellbore, a position indicated in Figure 1. At this initial time in

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the method, the well casing 15 is typically filled with a drilling fluid, or mud, that is employed, in part, to maintain pressure control over the well.

The cementing operation is initiated by inserting a flow plug in the form of a ball FP into the drill string 14 at the well surface and pumping a cement slurry behind the plug to force the ball to move downwardly through the drill string ahead of the cement and into the system 10 where it seats on the flow plug seat 29 of the lower plug 12. The dimensions of the ball FP are selected so that it will pass freely through the upper flow plug seat U29 and engage the seat 29 within the smaller diameter opening associated with the lower cement plug 12. It will be appreciated that during the pumping of fluids occurring with the assembly 10 in the position illustrated in Figure 1, the flapper gate sealing surfaces U22a and 22a and the seats U21a and 21a are protected from the erosive effects of the flowing fluids by the mandrel 13 and release sleeves U27 and 27. The seats U29 and 29 that are exposed to the flowing fluids are formed in the high-strength steel of the release sleeve and are resistant to erosion.

Once the ball FP has seated on the seat 29, a closure mechanism is created such that continued pumping of fluid creates a pressure differential between the fluid in the tool 13 upstream of the ball and that downstream of the ball. When the pressure differential is sufficiently great, the pressure induced force acting on the sleeve 27 through the ball FP operates as a release mechanism that shears pins 30 and releases the sleeve from its engagement with the mandrel 17. The O-ring seals surrounding the sleeve maintain a seal with the wall 20a of the seal support and continued application of the pressure

differential across the ball and seat seal shifts the sleeve 27 downwardly into the position illustrated in Figure 2.

At the end of the downshifted position, the sleeve 27 is prevented from continued downward movement within the mandrel 17 by a lip 17b formed along the base of the mandrel. In this lower position, the dog sets 25a and 25b function as a release mechanism freed to move radially inwardly, which releases the lower plug 12 from engagement with the mandrel 17. Shifting the sleeve 27 also opens the radial ports 35 and permits the pressurized cement slurry to flow into the annulus area A.

Continued pumping from the surface pressurizes the fluid in the annular area A located between the axial ends of the upper and lower plugs 11 and 12 and between the casing 15 and the mandrel 17. In the configuration illustrated in Figure 2, the casing 15 is sealed by the combined operation of the outer seal 18, the seal support 20, the sleeve 27, the flapper valve mount 21, the ball FP, the mandrel 17 and the seal ring 33.

When the pressure in the area A becomes sufficiently greater than that in a pressure area B below the plug 12, the plug 12 is moved axially along the mandrel 17 and pushed off of the mandrel 17 into a position such as illustrated in Figure 3. Once the plug 12 clears the mandrel, the spring loaded flapper closure gate 22 is free to snap closed and seal the central opening through the plug. The closed flapper gate functions as a one-way valve that prevents fluid flow from the pressure area A to the pressure area B. The application of pressure to the cement slurry in the area A causes the plug to advance downwardly through

the casing 15. During this procedure, the ball FP and sleeve 27 are retained within the mandrel 17 as the cement slurry flows into the casing 15.

The cement slurry driving the wiper plug 12 downwardly is pumped into the casing until a calculated amount of the cement, sufficient to adequately cement the casing into the wellbore, has been introduced into the drill pipe and casing. A second flow plug in the form of a ball UFP is then introduced into the drill string at the well surface and drilling fluid is pumped down the drill string behind the ball to move the ball through the drill pipe to the running tool.

The diameter of the second ball UFP is larger than that of the first ball FP and is larger than the diameter of the seat U29 so that the ball lands upon and seats within the seat U29. The application of sufficient pressure in the tool 13 above the ball UFP causes the shear pins U30 to shear permitting the sleeve U27 to shift downwardly into the position illustrated in Figure 4. The downward movement of the sleeve U27 is stopped when it engages the top of the lower sleeve 27.

In the position illustrated in Figure 4, the reduced diameter areas U28a and U28b register with the internal radial ends of the dog sets U25a and U25b, respectively, permitting the dogs to retract radially which in turn frees the upper plug 12 from the mandrel 17. Shifting the sleeve U27 downwardly also opens the large bore radial ports U35 so that the pressure being applied through the drill pipe 14 is applied into an annular area C intermediate the mandrel 17 and the surrounding casing 15 and above the plug 12.

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As with the lower plug 11, the upper plug 12 cooperates with the mandrel 17, the release sleeve 27 and the flow plug ball UFP to isolate the higher pressure in the area C from an area of lower pressure D below the plug 12. The pressure differential between the area C and the area D causes the plug 12 to move downwardly over the mandrel 17 until it is free of the mandrel as indicated in Figure 5. Once the plug 12 has cleared the mandrel, the spring-loaded flapper valve U22 snaps closed so that the plug 12 again effectively seals the areas C and D from each other. The continued application of pressure above the plug 12 in the area C forces the plug to move downwardly through the casing 15, moving the cement slurry contained between the plugs 11 and 12. During this procedure, the ball UFP and sleeve U27 are retained within the mandrel 17 as the drilling fluid flows into the casing.

When the bottom plug 12 engages and seals the bottom of the casing string 15, the pressure of the cement slurry in the casing ruptures the disk 23. Cement is then forced through the plug 12 via the opening created by the rupture of the disk 23 whereupon the cement exits the bottom (not illustrated) of the casing and returns back toward the well surface in the annulus between the casing and the surrounding wellbore in a manner well known in cementing procedures. Cement continues to be displaced ahead of the moving upper plug 11 until the upper plug 11 engages and stops against the top of the lower plug 12.

The running tool 13, as indicated in Figure 5, remains connected to the drill string 14 during the cementing process and can be retrieved to the surface

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with the withdrawal of the drill string. The major components of the running tool 13 may be fabricated from high-strength, thin walled steel and other high-strength materials that would be difficult to drill out had they been a part of the assemblies pumped downhole. The mandrel 17, balls FP and UFP and sleeves 27 and U27 may be retrieved, cleaned, redressed and run again in another cementing operation.

Figure 6 of the drawings illustrates a combination tool indicated generally at 101 comprising a fillup tool combined with a cementing assembly. The combination tool 101 is equipped with a remotely set cementing plug assembly of the present invention, indicated generally at 110. The combination tool 101 supports the cementing plug assembly 110 of the present invention within the top joint 111 of a casing string 112 . The casing string 112 extends through a drilling rig floor 120 into the well bore (not illustrated). The cementing plug assembly 110 is a dual plug assembly comprised of an upper plug 122 and a lower plug 124 . The assembly 110 is constructed and operated substantially the same as the assembly 10 described in Figures 1-5.

The combination tool 101 carries the cementing plug assembly 110 on a setting tool 135 secured to the lower end of the combination tool. The upper end of the assembly 110 is connected to supply lines that provide drilling fluid and a cement slurry to be pumped into the casing 112 through the combination tool 101. The combination tool 101 includes a lower equalizing valve 136 connected to a mandrel 138 which in turn connects to an upper equalizing valve

140. The valve 140 connects to a packer cup assembly 150 that provides a seal between the inside of the casing joint 111 and the combination tool 101.

The upper end of the packer cup assembly 150 connects with a cementing manifold 160 through which a cement slurry and drilling fluids may be selectively introduced into the casing 112. A cement port connection 162 provides access into the manifold 168 for a cement slurry introduced through a supply line 163. The upper end of the manifold 160 is connected to a top drive adapter or hook adapter 170 through which drilling fluids may be pumped through the combination tool 101 into the casing 112.

A ball drop injection assembly 180 communicates through the cementing manifold 160 for selectively inserting setting balls into the manifold as required to remotely launch the cementing plugs 122 and 124 from the running tool 135. In the embodiment of Figure 6, the ball injection assembly 180 is designed to hold two setting balls, a smaller ball 181 and a larger ball 182. Figures 6 illustrates the larger setting ball 182 in place within the injection assembly 180. The smaller setting ball 181 is illustrated in Figure 6 in sealing position with the lower cementing plug 124 after having been injected into the combination tool 101 from the assembly 180.

A remote control assembly 190 remotely controls the release of balls within the ball drop injection assembly 180 via electrical signals and fluid pressure applied through control lines 192. Control buttons 195, 197 and 198 on the control consoles are used to remotely control the launching of the wiper

plugs and the closing of the central flow opening through the combination tool 101

In the operation of the embodiment of the invention illustrated in Figure 6, a mud saver valve (not illustrated) used during the placement of the major length of the casing string into the well bore is removed from the fillup tool 101 and replaced with the dual plug assembly 110. The combination tool 101 with the plug assembly 110 attached is then lowered into the top of the casing string joint 111. As when operating as a fillup tool, the packer cup portion of the tool 101 provides a fluid seal between the tool 101 and the casing to prevent the escape of fluids being pumped into the casing.

In the configuration illustrated in Figure 6, with the plug assembly 110 attached to the bottom of the combination tool, and with both balls contained within the injection assembly 180, drilling fluids may be pumped into and circulated through the combination tool and casing string and additional joints of casing may be added to the string as required to reach the desired setting depth for the casing string. When the casing string reaches the desired setting depth, and after properly conditioning the well bore by circulating drilling fluids, the bottom cementing plug is remotely released from the remote console 190 by manually depressing the bottom release button 195.

Depressing the button 195 effects the injection of the ball 181, which is the smaller of two setting balls contained within the ball drop head assembly 180, into the cementing manifold 160. Following release of the smaller ball into the cementing manifold, a cement slurry is pumped into the manifold through the

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cement port connection 162. The cement slurry and gravity move the ball 181 into the seated position within the lower plug 124 as illustrated in Figure 6. The setting ball 181 seals the running tool flow passage and causes the lower plug to launch into the casing string in the manner previously described with reference to the embodiments illustrated in Figures 1 through 5.

Once sufficient cement has been pumped into the casing string 112, the button 197 of the remote control console 190 is depressed to inject the larger setting ball 182 from the ball drop injection assembly 180 into the manifold 160. Pumping of cement is then terminated and drilling fluid is pumped into the combination tool 101 through the adapter 170. Gravity and the drilling fluid move the ball 182 into sealing engagement within the running tool mandrel in the upper cementing plug 122. The upper cementing plug 122 is launched from the running tool 135 to displace the cement in the casing and wipe the inside of the casing wall, substantially as described previously with respect to the embodiment-of Figures 1-5. Subsequent operation of the cementing process is substantially as described previously with respect to the embodiment of Figures 1-5.

The design of the present invention permits substantially larger flow openings to be formed through remotely set, multiplug cementing assemblies. A conventional remotely released multiplug assembly of the prior art will have a minimum central opening available for the passage of the cement slurry and the drilling fluids of as small as 1.5 inches. In a two plug system of the present invention, the smallest internal diameter of the flow passage is 1.75 inches. If

only a single plug is used, the smallest internal diameter is 2 inches and that of a prior art plug is 1.875 inches. Thus, it will be appreciated that the flow passage opening size possible with the running tool and dual plug assembly of the present invention represents an increase of 17% over that of the prior art.

The following table illustrates the greater number of components and the larger component dimensions required in cementing tools of the prior art design as compared with the design of the present invention.

Prior Art Components	**OD (inches)**	**ID (inches)**
Collet Retainer (High-strength Steel)	4.500	3.700
Collet (aluminum)	3.690	2.998
Releasing sleeve (aluminum)	2.990	1.875
Connector (aluminum)	2.560	1.875
Ball Seat (aluminum)	2.250	1.500

Multi-plug Assembly of the Present Invention - All parts High-strength Steel - 110-125 ksi yield strength	**OD (inches)**	**ID (inches)**
Mandrel	3.500	2.750
#1 Releasing Sleeve	2.742	2.000
#2 Releasing Sleeve	2.742	1.750

As may be noted from the table, the diameters of the central flow dimensions made available with the novel cementing assembly of the present invention have been increased by a factor of approximately 17%. Moreover, as compared with the plugs of the present invention, the volume of metal remaining with the prior art plugs traveling to the bottom of the casing string is substantially greater. It will also be appreciated that the reduced volume of metal in the plugs of the present invention allows the plugs to be more rapidly and easily milled up or drilled out as compared with those of the prior art.

While preferred embodiments of the present invention have been illustrated in detail, it is apparent that modifications and adaptations of the preferred embodiments will occur to those skilled in the art and such modifications and adaptations are within the spirit and scope of the present inventions as more completely set forth in the following claims.

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